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INVESTIGATION OF ENERGY SAVING POTENTIAL IN A SOUTH AFRICAN CEMENT FINISHING MILLPLANT

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ABSTRACT

The cement industry is an industrial sub-sector with high energy intensity. It represents nearly 15% of the total energy used by industries.Many energy-saving programs and strategies have been launched and adopted in this sector. Both technological and non-technological restrictions must be addressed when implementing the best solutions for a specific cement plant. This study examines energy consumption and potential saving opportunities using exploratory questionnaires in a South African cement finishing plant. Respondentsanswered questions on energy saving potential, highlighting the reasons for adopting cost-saving energy efficiency strategies in aSouth African cement finishing plant.

A significant amount of energycan be savedby focusing on energy consumption reduction initiatives through process optimization, production management, and new technologies. This study used a questionnaire to determine the energy-saving potential of a cement finishing plant. This study provides a fundamental understanding of the energy efficiency status of cement plants and the energy saving potential of such plants. The findings reveal the maximum savings potential that cement plants can achieveby implementing various measures related to the case study plant. The results project a substantial energy savings potential in cost-savings (Rand), energy investment (Rand) and payback periods.

KEYWORDS: Cement Industry, Energy Saving, Energy Consumption & Industrial Energy Efficiency

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Original Article

1. INTRODUCTION

Global warming and climate change are mainly due to greenhouse gas (GHG) emissions related to energy consumption. In 2012, the industrial sector consumed 28.3% of the world's total energy use and emitted 38.5% of total carbon dioxide (CO_2) [1]. The non-metallic minerals industry ranked third highestamong industrial energy userswith about 12% of the overall energy use worldwide, in which the cement sector consumed the most energy [2-7]. In 2012, the cement industry consumed around 8.5% of total industrial energy consumption and contributed 34% of direct industrial CO_2emissions[8].Before now, most industries thought that changing to low-efficiency equipment from high-efficiency equipment might significantly impact their energy use, thereby lowering their production cost.However, simple modification in the managers' and employees' behavior and attitudes on energy use can alsopromote efficiency and energy savings[9]. Therefore, substantial efforts have been made to formulate appropriate standards to improveenergy-savings effects.

Numerous countries worldwide have addressed the lack of energy efficiency measures, and many studies have been conducted on energy management [10, 11]. Previous studies on the energy management field within the cement sector include those in China [12-14], Thailand [15, 16], the US [17], Ethiopia [18] and Europe[19-21]. Improvement of energy efficiency in energy-intensive industries such as cement plants cansignificantly impact their

economic competitiveness on the world market [22, 23].

Brunke and Blesl[20] calculated the energy-saving and CO_2reduction potential of 21 identified measures at cement production plants in Germany and the result showed that the economic saving and reduction potential for the year 2013 was 4% for fuel, 0.7% for electricity, and 3.4% for process-related CO_2 emissions compared to 2012.Castanon et al. [24] performed a statistical analysis using Partial Least Squares Projections to Latent Structure (PLS) regression to optimize the production process and the relationship between kiln parameters and clinker quality in a Spanish cement plant.The results showed that lowering the temperature of kiln sintering by about 50°C has the same quality level as the final product while reducing CO_2 emissions and fuel consumption.

Energy Consumption and Energy Demand in South Africa

South Africaproducesabout 40% of the electricity in Africa [25].The South African electricity sector is dominated by Eskom, the national energy supplier which produces almost 90% of the country's electricity[25] (Figure 1).Municipalities, retailers and private generators are responsible for thebalance.

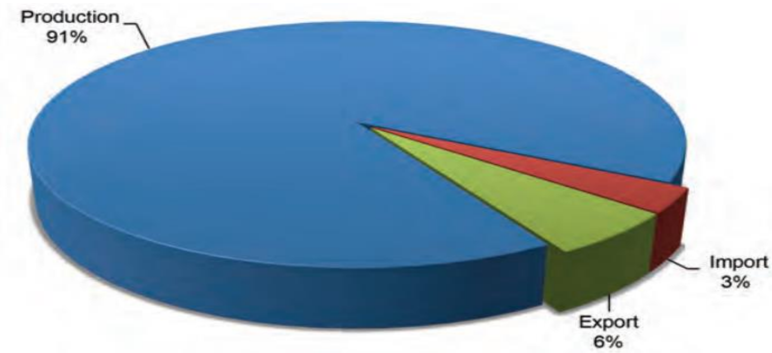

Figure 1: Electricity Supply, 2016 [26, 27].

South Africa can become more energy efficient. South Africa's energy sector is responsible for 15% of the country's energy-driven economy[28], with coal representing 70% of the energy supply and 93% from electricity production[26, 27]. In 2019 South Africa ranked as the 7th largest CO_2 emitter worldwide and 1st in Africa due to the country's excessive reliance on coal [28].Energy demand includesthe total of all the main energy sources ingested by a nation or territory such as coal, petroleum, natural gas, renewable energies and nuclear energy. Final energy is the total energy used by various economic sectors such as transport, industries and service companies.

Energy is the basisof the South African economy. It is a critical industry that generates jobs and value by extracting, converting, and delivering energy goods and services across the country's economy. South Africans have steadily increased their energy demand in recent years, combined with anincreased focus on industrialization and large-scale electrification plans in deep rural areas. Figure 2 illustrates the percentage of energy consumed by different economic sectors in South Africa.Transportation industries, agriculture, residential, commercial and public services are the five sectors identified. The "non-specified" sector means unaccounted energy, i.e., the energy that is not included in a specific sector.

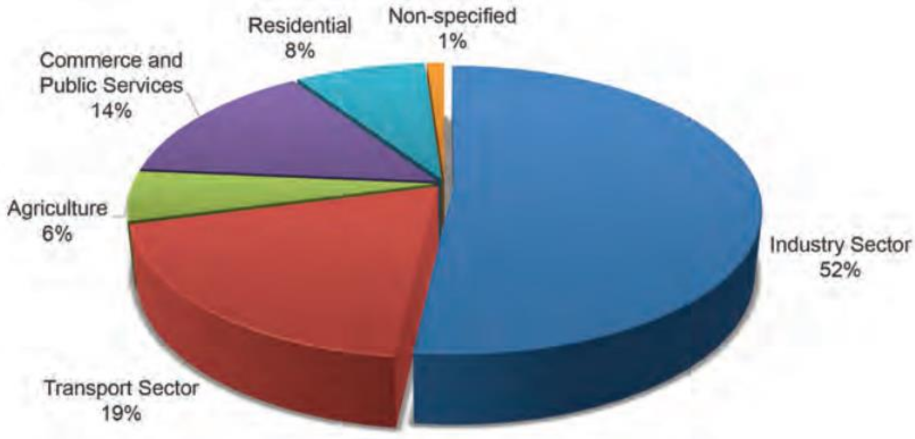

Figure 2: Energy Demand by Sector, 2016 [26, 27].

The energy demand by the industrial sub-sector is as follows: iron and steel 18%, petrochemicals and chemicals 14% are the top energy consumers in the sector. Quarrying and mining represented 10% of industrial consumption, while non-metallic and non-ferrous metals represented 5% and 8% respectively.The other sub-sectors represented 2% or less of energy consumption. In 2016, the industrial sector consumed 52% of the total energy supplied. Asshown in Figure 3, coal was the most widely used energy source in the industrial sector, accounting for 35% of total consumption. Electricity and renewables followed closely behind, both at 25%.Petroleum products and gas represent respectively 10% and 5% of the total energy use within the sector.

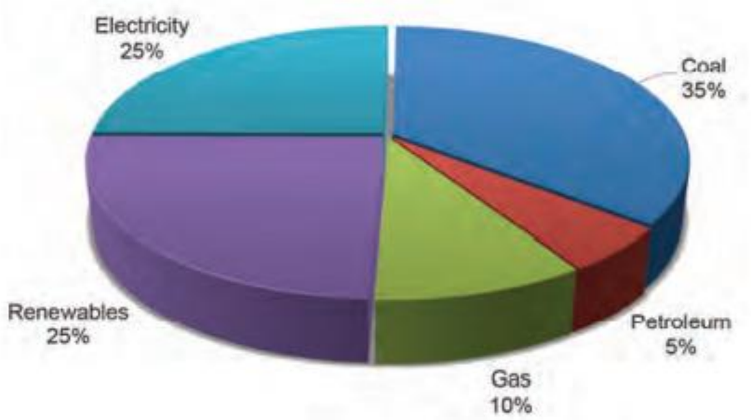

Figure 3: Energy Demand in the Industrial Sector, 2016 [26, 27].

3. INDUSTRIAL ENERGY EFFICIENCY TRENDS

South Africa is regarded as the continent's most developedcountry [29]. In 2019 the Association of Energy Engineers (AEE) awarded the International Energy Project of the Year to the programin South Africa [30].

3.1 Energy Saving

Energy-saving is defined as a reduction in energy usage without compromising energy efficiency. The use of inverters (AC drives) to speed up the production process is an example of energy-saving in the industrial sectorand the speed can be varied according to the need.

Other examples include compressors, conveyors belts and pumps.

3.2 Energy-Saving Technologies in the Cement Industry

Energy efficiency is concerned with the reduction ofenergyrequired to accomplish the same work[31]. Industrial energy efficiency measures focus mainly on process optimization and address the suitable replacement of current machinery [32].The cement production process can be divided into three major stages [33]:

- Preparation of raw material.
- The productionClinker.
- Cement grinding.

The preparation of raw materials generally depends on electricity use [34].Integration of the electricity use with efficient technologies high-pressure roller presses (pre-grinding for ball mills), improved classifiers and separators, vertical mills, multi-stage pre-heater with pre-calciner, efficient materials homogenization, efficient electric motors, variable speed drives (raw mill fans) [15]. Other technologies are the use of an efficient roller mill, efficient transport systems (raw materials preparation) [18], efficient fan with inverter (raw mill), with closed-circuit classifiers (wash mill) [35] and bucket elevator (raw meal transport) [13]. Substituting the traditional ball mills with more efficient mills,for instance,a roller press for raw materials pre-grinding can reduce electricity usage. Using high-efficiency classifiers and separators can prevent over-grinding, thereby reducing electricity use.Raw materials homogenization improves kiln flame ability, thereby reducing energy consumption [34]. Clinker production is more dependent on energy consumption than other cement production stages, and the kiln consumes the most energy in the process [34]. Energy efficiency technology can significantly reduce energy usage, including in clinker production [34, 36, 37].The energy efficiency of clinker production, alternative fuels, and alternative raw materials are three main methods to be considered for reducing carbon emissions [38, 39]. Adry rotary kiln with preheater and pre-calciner is the most energy-efficient kiln technology [40]. Changing from wet process to dry process saves up to 50% energy and reduces CO_2 emissions by 20% [41]. It is important to know that all cement kilns employ the dry method in South Africa [42]. Numerous innovative technologies can improve the cement plant efficiency [43].

4. METHODOLOGY

The study'sdata was obtained using a questionnaire centred on existing energy efficiency and energy saving in aSouth African cement plant. A questionnaire gives the respondent a chance to think about the question before providing an answer. Since the questionnaire is a more anonymous structure, this permits respondents to share their thoughts. Open-ended and closed-ended questions were used for respondents. Davies and Hughes [44] stated that questionnaires are often used to gather essential information and a research tool. Case studies focus on a comprehensive analysis of a single person, organization, or event to investigate the causes, including quantitative evidence. Furthermore, it is based on several sources of proof and denotes the benefits of previous theoretical claims. The strength of this kind of study approach is to get detailed and valuable data from several factors.

4.1 Case Study

This research was carried out in one of the largest South African Portland cement producers. Within the facility, there are approximately 150 employees. The response rate was poor. Fifty-five questionnaires were distributed among the

production and engineering workers; 15 were sentthroughemail and 40 were distributed physically to the engineering staff. Seventeen respondents answered the questionnaire. This study was conducted between March and May 2017.

5. RESULT AND DISCUSSIONS

5.1 Plant Energy Saving Practices

It is critical to define energy-saving techniques, energy waste, and proper energy utilization. All respondents responded to the presence of opportunities for energy-saving in the plant. Figure 4 reveals that 3 respondents strongly agreed, 6 respondents agreedthat there is a waste of energy, 5 respondents unsure whether there is waste or not, while 3 respondents disagreed that energy is wasted within the plant.

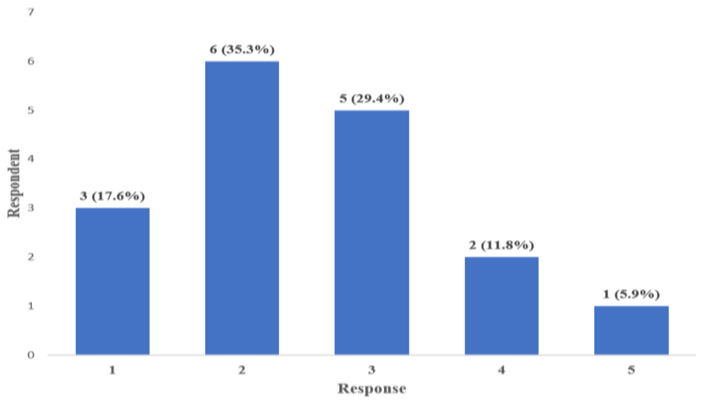

Figure 4: Energy-Saving Opportunities Result from the Plant.

Figure 5 reveals that 17.6% of the respondents strongly agreed, while 35.3% agreed, 29.4% were unsure, while 17.7% respondents disagreed or strongly disagreed that the plant has energy-savingmethods in place.

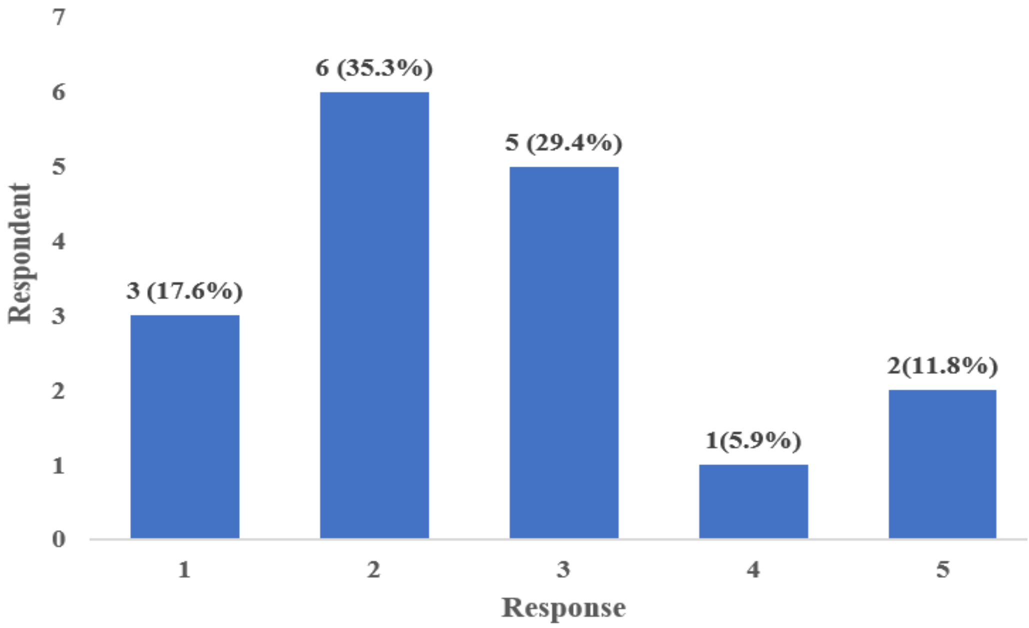

Figure 5: Energy-Saving Methods within the Plant.

Figure 6 reveals that 11 respondents stated that they turn off machines, computers, equipment, or lightswhen they are not in use, 3 were neutral,whereas 3 respondents did not.

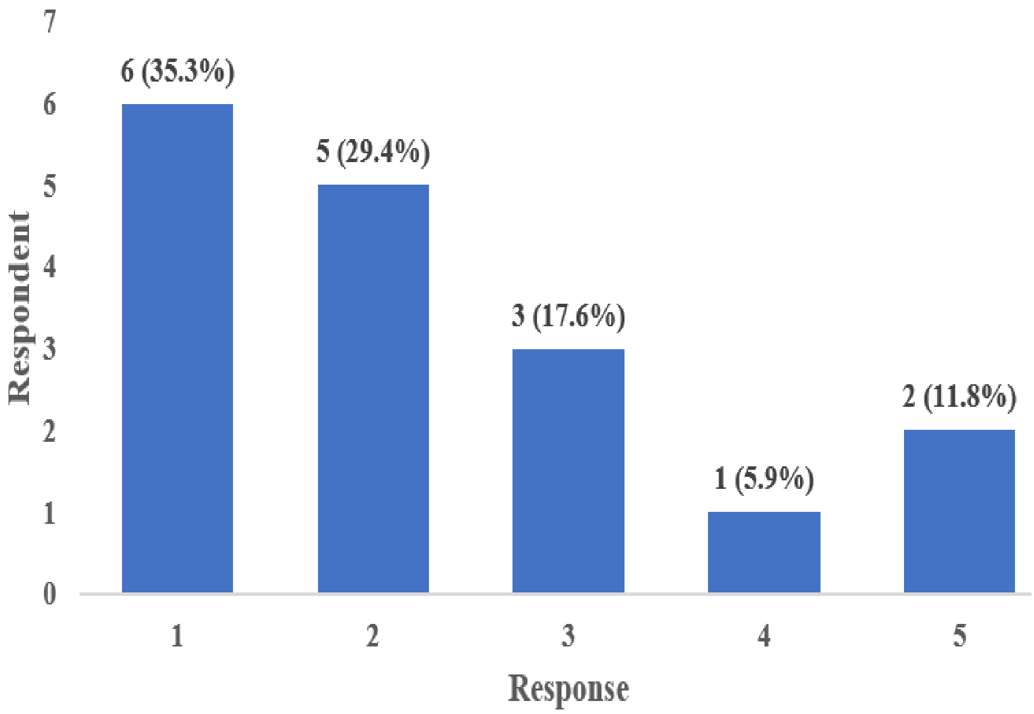

Figure 6: Result from Electrical Appliances Information.

Approximately 88.2% of respondents perceivedthat energy training programs are necessary, whereas 11.8% perceivedthat energy training programs are unnecessary.

5.2 Plant Energy Consumption and Data Trends

As shown in Figure 7, the available information on energy consumption was rated low by the plant workers, while the installation of energy sub-metering was rated high (12 respondents), as shown in Figure 8.

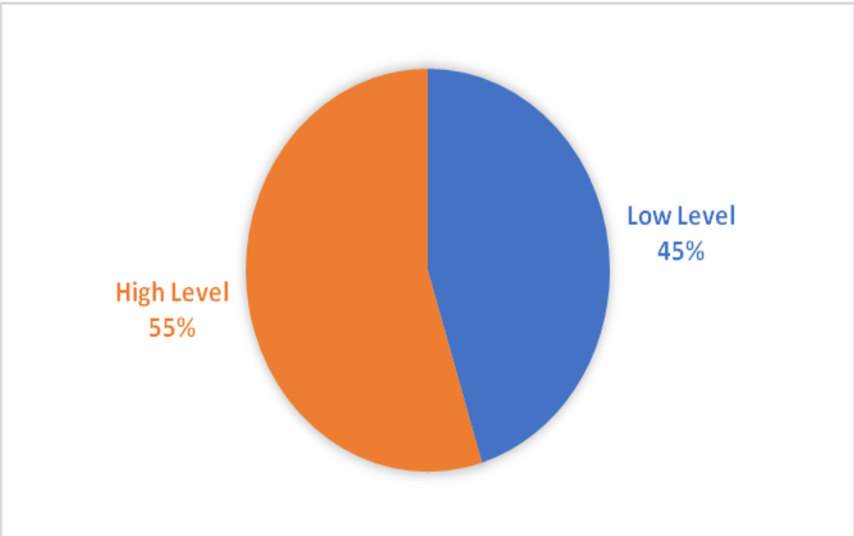

Figure 7: Plant Energy Consumption Information.

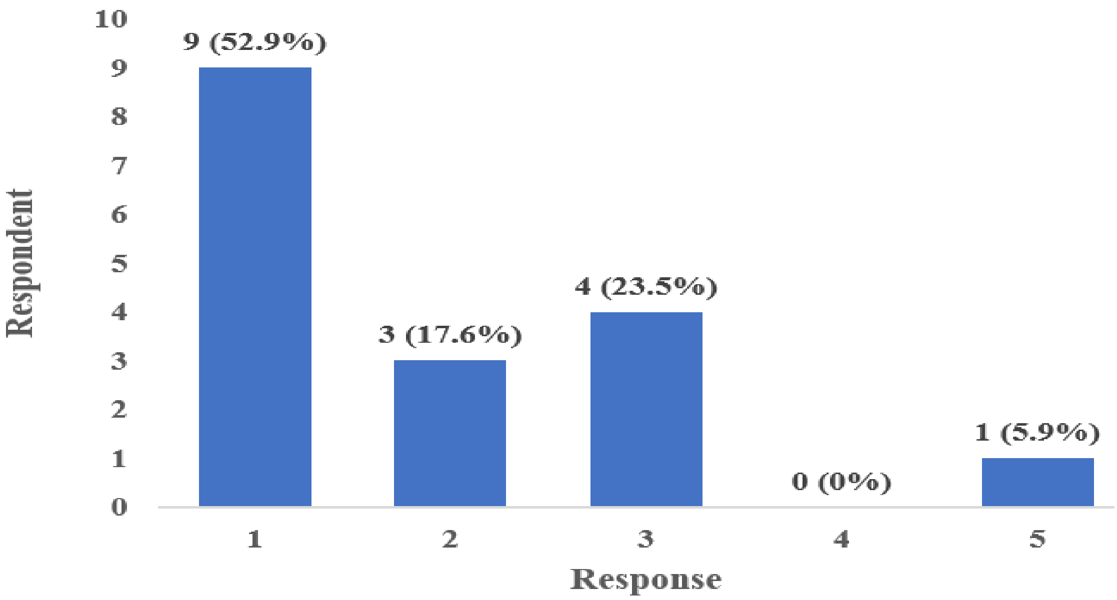

Figure 8: Energy Sub-Meter Information.

Availability of data on energy consumption trends was visible within the plant, as shown in Figure 9. There is no historical record of energy-saving. This indicates that environmental performance is not as essential as cost savings within the energy efficiency decision-making in the plant (8 respondents). However, some respondents reported self-motivation and encouragement concerning environmental performance improvement among colleagues.

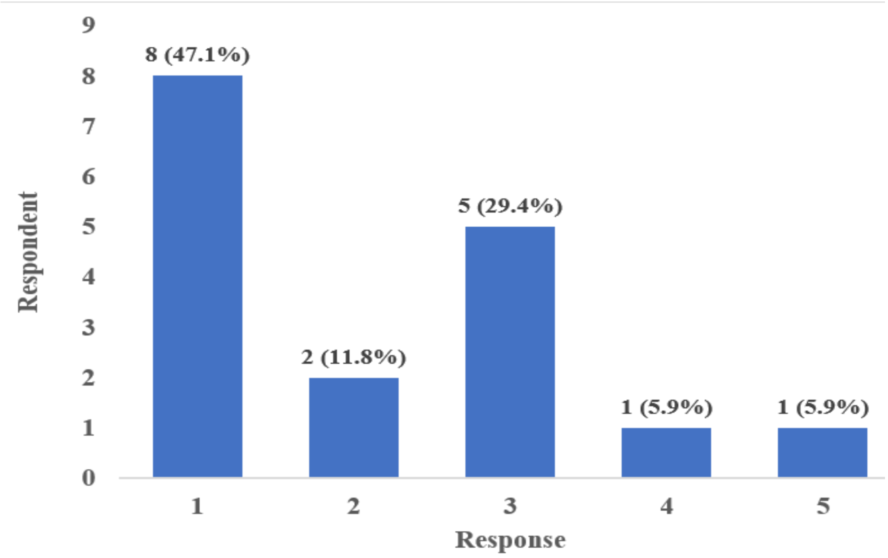

Figure 9: Availability of Energy Consumption Data Trends.

5.2.1 Energy Consumption Units

Participants were asked which units or cement equipment within the plant that consumed used the most energy. Eleven respondents said the cement mill, 5saidthe roller press, and 1said packaging,as shown in Figure 10.

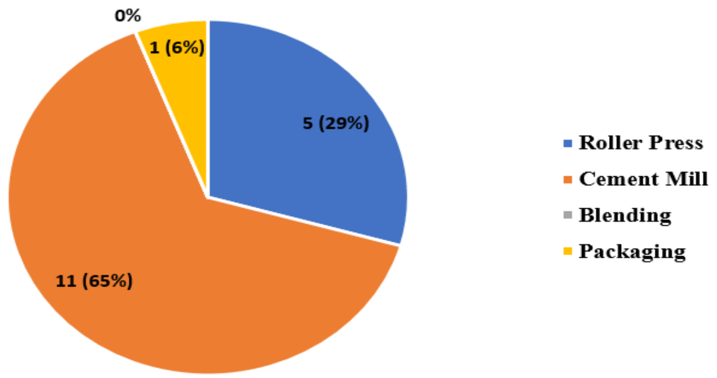

Figure10: The Energy Consumption Units in the Plant.

The questionsidentifiedthe reasons for energy loss within the plant as follows:

- Keeping the production machine running at peak hours.
- Heavy energy-consumingequipment.
- Lack of effective induction motors for plant operation.
- Using of outdated equipment for production.
- Conveyor belt moving when there is no production.
- Poor maintenance of plantmachinery
- Lack of awareness about the need to save energy.

The following are the steps identified by the participants regardingenergy saving.

- The requirementfor storage facilities to help reducethe amount of energy used in material crushing.
- Usingshell ring drivesinstead of the drive motor.
- Reduce circulating load.
- Improvingthe mill systemseparator.
- The use of energy-efficient equipment.
- Natural light use optimization.
- Upgrade the spinning mill electricityreduction.
- Hourly efficient power usage.
- Energy-saving exercises (stop production during peak hours).
- Energy audits for processes.
- Energy-saving practices awareness among staff.

- The use of solar panels.
- The shutdown of machinerieswhen they are not in use.

5.3 Approaches for Maintaining Energy Efficiency

Figure 11 shows that 10 out of the 17 respondents said yes there is punishment for non-compliance with energy saving measures, whereas 7 said no there is not. Eleven respondents answered thatthere are no motivations to comply with energy-savingmethods, whereas 6 respondents answered thatthere are motivations to comply with energy savingmethods.

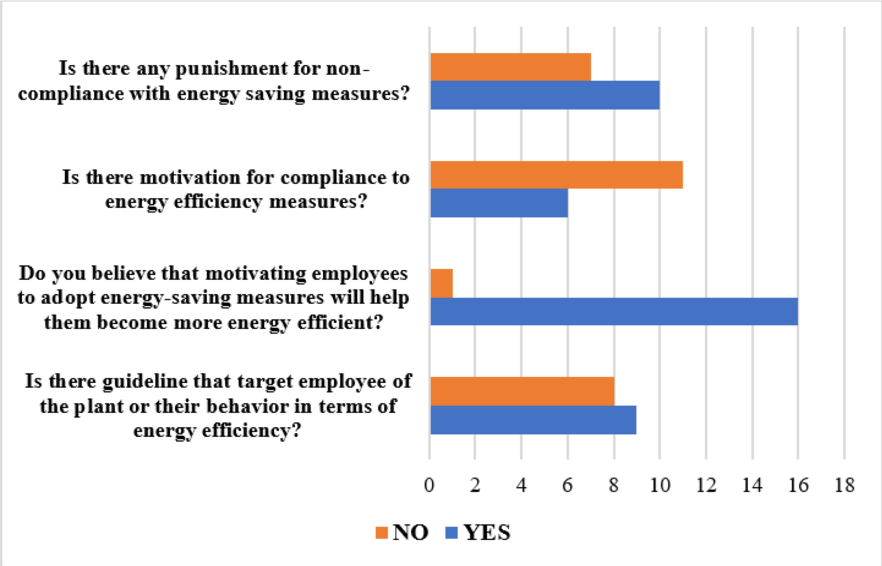

Figure 11: Rating of Approaches for Maintaining Energy Efficiency.

Most respondents (16) believed that energy efficiency motivations would improve employee behavior to increase energy efficiency, with 1 respondent disagreeing. Nine respondents indicated that there are guidelines for the behavior of employees in terms of energy efficiency, while 8 respondents indicated that no guidelines existed.

5.4 Energy Efficiency Projects Significant Factors

As shown in Figure 12, 16 respondents agreed with the viewof all the Significant factors in energy efficiency projectsas factors influencing energy efficiency projects significantly, whereas 1 respondent failed to regard these factors as relevant.

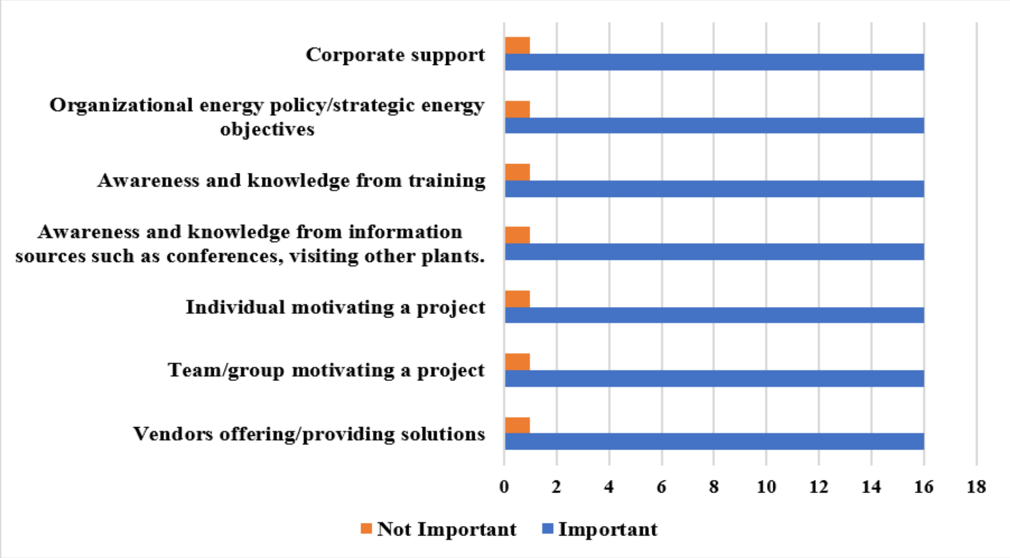

Figure 11: Rating of Approaches for Maintaining Energy Efficiency.

Respondents made the following suggestions: implementation opportunities to reduce costs and energy consumption, strict implementation of energy policies, energy consumption management, punishment for energy wastage, communication with energy users, investment to reduce energy consumption and includemodern integrated energy-saving technologies. Respondents were askedan open-ended question regarding whether the local authorities and the stakeholders hadmade sufficientefforts to achieve improvedenergy efficiencygoals; respondents replied that they had little awareness and that local stakeholders' response is insufficient.

5.5 Energy Efficiency Improvement Potential

The study measured the energy efficiency improvement potential utilizing maintenance best practices to understand better the employees' perceptions as shown in Figure 13.

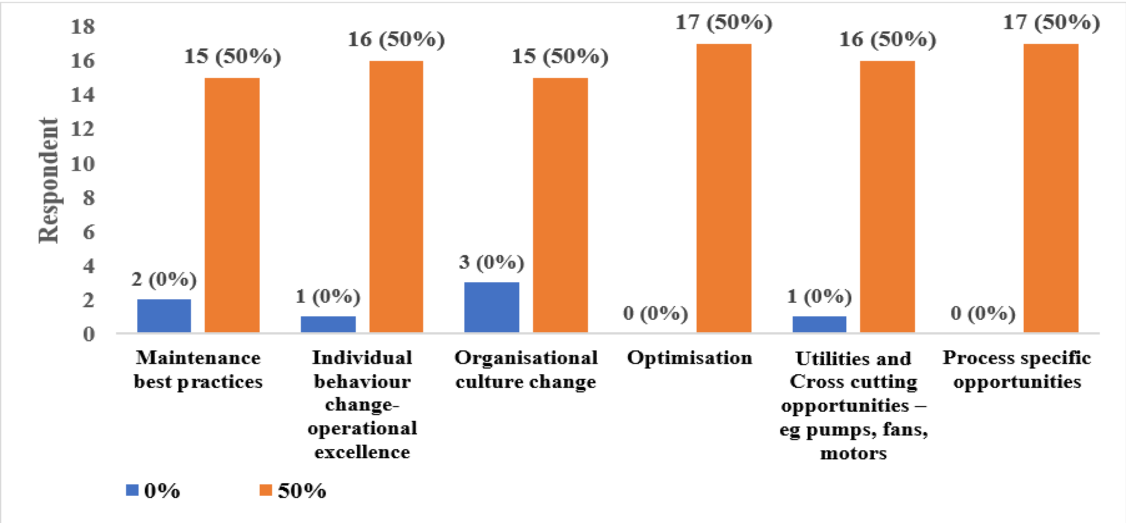

Figure 13: Potential for Energy Efficiency Improvement Result.

Figure 13 shows that all 17 respondents believe that both process-specific opportunities and optimization enhance energy

efficiency, that 16 respondents consider utilities and individual behavior change to enhance energy efficiency, and 15 respondents believe that organizational culture change and maintenance best practices are important for energy efficiency.

5.5.1 Using of Throttle Controls and Centrifuge Pumps

Data from respondents showed that adhering to the reduced energy consumption needs specific measures.Figure 14 shows that 10 respondents agreed that centrifuge pumps and throttle controls should be used to save energy use, while 6 respondents were neutral and 1 respondent disagreed.

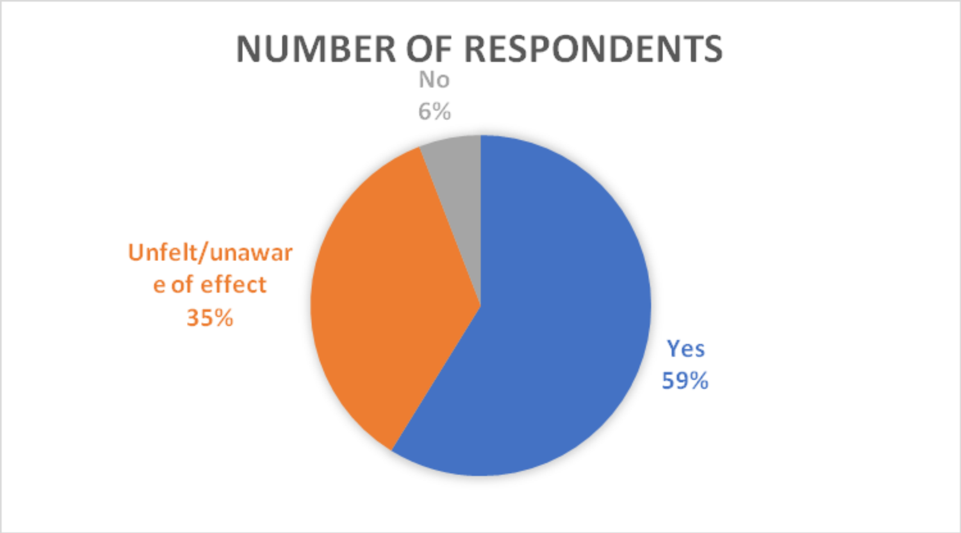

Table 14: Measures for Reducing Energy Consumption.

5.5.2 Energy-Saving through Lighting

In response to a question on energy-saving lighting systems using energy-saving fluorescent lamps (i.e.,substituting 38 mm fluorescents with 26 mm, usingcompact lamps instead of the tungsten filament and natural lightoptimization). 58.8% strongly agree, 11.8% agree, 23.5% are neutral, and 5.9% strongly disagree Figure 15. In response to energy-saving via lighting, 8 respondents agree, 6 are neutral, and 3respondents disagree as shown in Figure 16.

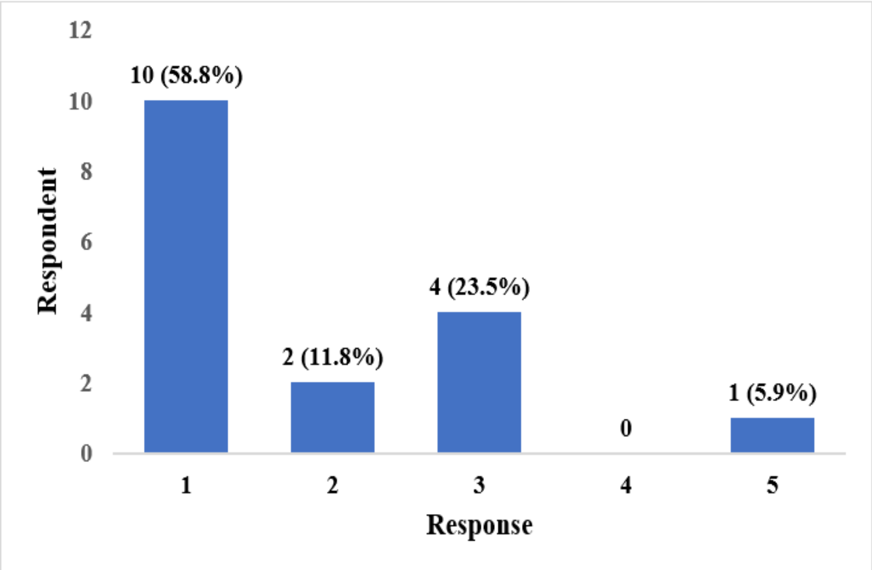

Figure15: Optimize the use of Natural Light.

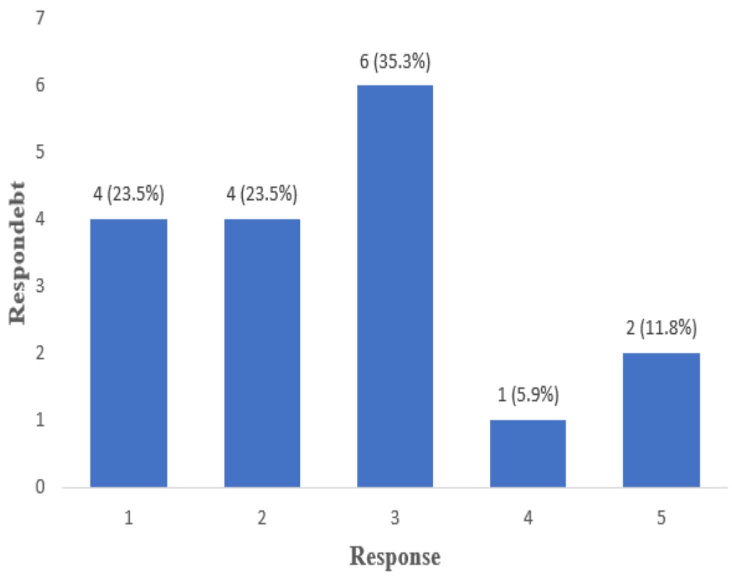

Figure 16: Reduceenergy Consumption through Lighting.

5.5.3 Energy Consumption Reduction Measures

Thirteen of the 17 respondents stated that the plant had adopted energy-saving measures, such as power factors, efficient motors, and automated power switches (for fans, pumps, conveyors, and other equipment when they are not in use). Whilethe remaining 4 believed that the plant did not implement suchmethods,as presentedin Figure 17.

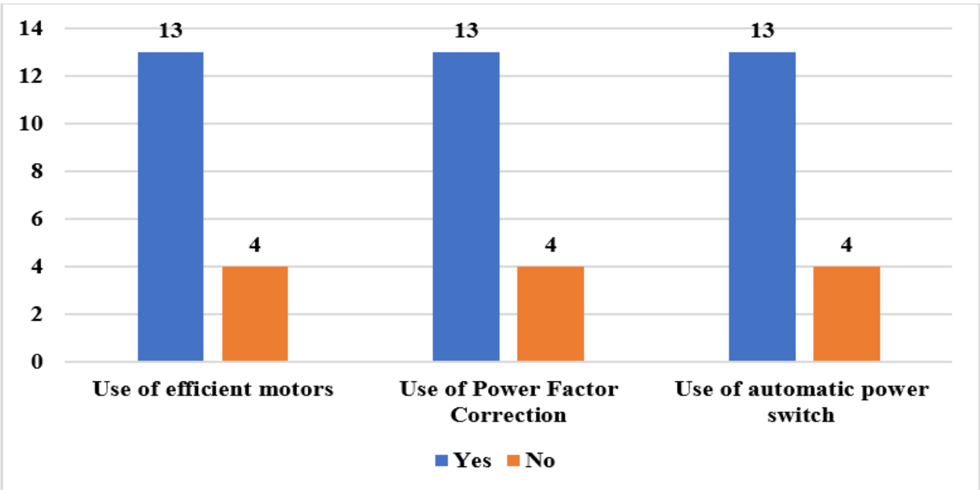

Figure 17: Rating of Measures for Reducing Energy Consumption.

CONCLUSIONS

This study investigated energy-saving potential in one of the oldest cement finishing mills in South Africa. A questionnaire-based study was conducted to identify potential savings within the plant. When evaluating energy savings opportunities in cement plant finishing mill, it is critical to keep the following in mind:

- If greater capacity is required, it is evident that it would be wise to consider the latest and more efficient milling technologies or combine the latest with older milling technologies.
- In situations where older technology is currently in use and in excellent working condition, the high capital cost of replacing it with the latest technology may make such initiatives financially unappealing. In these scenarios, companies must look at ways of operating the current systems more effectively, i.e., optimize operations with little capital investment.

The technical part of this study included the investigation of energy-saving potential within a cement plant. Therefore, we determined the cement finishing mill's energy-saving potential and calculated its cost-savings, energy investment, and payback periods. Considerable energy savings were estimated, as shown in Table 1. Consequently, the plant may save a lot of energy while considering the remaining areas.

Table 1: Energy-Saving Estimation of Different Methods[6]

Recommendations	Cost saving per annum (Rand)	Investment (Rand)	Simple payback
Improving system power factor using capacitors	2,467.00	15,814.00	6 years
Installation of variable frequency drive for motors	1,012,099.00	131,784.00	1 month
Use of energy efficient lighting Replacement of 38mm fluorescents with 26mm	44,219.00	53,613.00	14 months
Optimize the uses of natural light system	29,092.00	20,404.00	8 months
Use of efficient motors/ Use of automatic power switch	14,979.00	41,117.00	3 years

Lighting consumes verylittle energy in the cement plant. Nevertheless, there are energy-saving opportunities that can cost-effectively reduce energy consumption. Lighting is either utilized to deliver general ambient lighting during production, storage and offices, or to give certain areas low-bay lighting and task lighting. Fluorescent, radiant lights and compact fluorescent (CFL) are generally used for office lighting tasks.

All employees should understand energy use and organizational objectives for energy efficiency. The workers should get training in general skills and improving energy efficiency methods in their daily activities. Furthermore, the results of performance should frequently be assessed and presented to all staff recognizing high accomplishment. The following are some examples of energy-saving potential that workers can perform. Remove equipment that consumes too much energy. Turn off motors, fans and machines at the closing of workday or shift or during the breaks time, providingit does not affect production, safety,or the quality. Switch on equipment only when necessary at the starting time to achieve the proper parameters. The variable frequency driver (VFD) installation will require more capital investment and result in energy saving in the long run. Therefore, this study opens the door to more in-depth work, identifying the most efficient strategies for energy saving.

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